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AUTHOR Gorrell, Paul; Chen, Qiming
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ABSTRACT

Issues in syntactic processing, that aspect of the human sentence comprehension mechanism that recovers a syntactic structure for a given word string, are discussed. In particular, two structural ambiguities in Mandarin Chinese are examined and their successful parsing within the framework of minimal parsing models is discussed. Recent work investigating structural ambiguity in English is then related to the analysis of the Mandarin Chinese examples. As a result of the analysis, it is concluded that with this parsing design, the parser's response to structural ambiguity minimizes the need for reanalysis, computes multiple analyses based on available lexical and syntactic information, delays commitment to a unique analysis if sufficient information is unavailable, and does not postpone commitment if lexical material is left unlicensed or unstructured. The model, therefore, constrains both the parser's capacity for computing multiple analyses and its capacity for delaying commitment to a particular analysis. (MSE)

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Paul Gorrell and Qiming Chen

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MINIMAL COMMITMENT PARSING: TWO EXAMPLES FROM MANDARIN

Paul Gorrell and Qiming Chen
University of Maryland

0. Introduction

In this paper we will discuss a number of related issues concerned with syntactic processing, i.e. that aspect of the human sentence comprehension mechanism which recovers a syntactic structure for a given word string. In particular, we will examine two structural ambiguities in Mandarin and discuss how they can be successfully parsed within the framework of minimal commitment parsing models (Marcus, Hindle, & Flick 1983; Berwick & Weinberg 1985). We will then turn to a discussion of some recent experimental work investigating structural ambiguity in English and relate this to our analysis of the Mandarin examples.

We will take as our starting point a brief discussion of three current approaches to how the parser responds to structurally ambiguous word strings. A given word string is structurally ambiguous if it is compatible with more than one syntactic structure. These approaches are sketched in (1).

(1) Serial Models

A single 'preferred' structure is computed for an ambiguous string. If this structure is incompatible with subsequent material, reanalysis is required.

Parallel Models

Multiple structures are computed for an ambiguous string. At points of disambiguation, incompatible structures are abandoned.

Minimal Commitment Models

Commitment to a particular analysis is postponed until the appearance of disambiguating information.

Serial parsing models (e.g. Frazier & Rayner 1982; Ford, Bresnan, & Kaplan 1982) utilize various decision procedures for determining a preferred syntactic analysis at the onset of the ambiguity. If subsequent lexical material is incompatible with this analysis, then an additional process of reanalysis is required.

Parallel models (e.g. Chodorow 1976; Kurtzman 1985) compute multiple syntactic analyses for ambiguous word strings, abandoning those which are incompatible with subsequent information. Minimal commitment models delay commitment to a particular analysis either until a specified lookahead space is exhausted, or until disambiguating material is encountered. The intent of this delay is to allow a deterministic parse, where 'deterministic' is defined in the sense of Marcus (1980). All three models assume the parser structures incoming material as it is received, rather than waiting until a clause boundary is encountered or some specified amount of lexical material has been received (see Fodor, Bever, & Garrett 1974 for discussion).

1. Minimal Commitment Parsing

Our discussion of structural ambiguity in Mandarin assumes three properties of minimal commitment parsers: (i) hierarchical structure analysis uses the predicate dominates rather than directly dominates; (ii) an empty operator which is not part of the final syntactic analysis may be posited so long as it is not coindexed with an element in an argument position; (iii) no lookahead device is used.

The first property allows a deterministic parse of temporary ambiguities in English such as (2).

(2) John knew the old woman ...

Here, the NP the old woman may function either as the direct object of the verb knew (e.g. the old woman quite well) or as the subject of an embedded clause (e.g. the old woman was ill). The structural realizations of these two readings are shown in (3).

(3) a. $[_{VP}$ knew $[_{NP}$ the old woman] quite well]

b. $[_{VP}$ knew $[_{S}\cdot[_{S}[_{NP}$ the old woman] was ill]]]]

At the point at which the NP the old woman is encountered, the parser commits itself only to the analysis that the VP dominates the NP. If subsequent lexical material, e.g. the predicate was ill, proves the NP to be further embedded within the VP, then additional domination statements are added (e.g. VP dominates S, S dominates NP).

The second property allows a deterministic parse of ambiguities involving parasitic gaps such as (4).

(4) Which article did you discuss without reading?

Following Chomsky (1986), we take the structure of (4) to be (5).

(5) [Which book$_i$ [did you discuss t_i without [O_i [reading e_i

In (5), the parasitic gap 'e' is bound by the empty operator 'O' in the embedded COMP. As first noted by Fodor (1985), the fact that a parasitic gap is optional in sentences such as (4) poses serious problems for a deterministic parser. If we assume that parasitic gap constructions involve an empty operator which binds the gap, the specific problem which arises is that a deterministic parser, in order to avoid postulating structure which is not part of the final syntactic analysis, must posit an empty operator only if the embedded clause does, in fact contain a parasitic gap. But without resorting to a lookahead device, it cannot know this until after it must decide on the presence or absence of an empty operator.

Nor is it possible for the parser to simply wait until the embedded clause is parsed and rely upon local subcategorization information, and then decide whether or not to place an operator in COMP. To understand why this is so we must examine sentences such as (6) and (7) from the viewpoint of a deterministic parser such as the one proposed in Berwick & Weinberg (1984).

(6) What did you say [that Bill would eat tonight?

(7) Did you say [that Bill would eat tonight?

The problem for the parser is to insert a gap following eat in (6) but not to do so in (7). The Berwick & Weinberg parser will only postulate a gap if there is an available antecedent for it. The search space for an antecedent is the left context subjacent to the potential trace position. In order to insure that an available antecedent is within this domain, the parser will place a trace in the embedded COMP which serves as the antecedent for the gap. The decision to place this intermediate trace in the embedded COMP is based on the presence of the WH-phrase in the matrix COMP. Thus in (7), no trace is inserted into the embedded COMP and no gap is postulated after the verb eat.

The problem which parasitic gaps pose for such a parsing model is that the presence of an overt WH-phrase does not insure the existence of a parasitic gap. This is because a parasitic gap is bound by a non-overt, or empty, operator. The solution proposed by Berwick &

Weinberg (1985) is to define determinism in such a way that an empty operator may be posited even if it may end up not binding a parasitic gap.

The proposed solution is as follows: the Berwick & Weinberg parser is a two-stage device. The first stage involves structure building, the second stage concerns indexation. Thus, an empty operator may be posited by the first-stage device without receiving an index. If the clause, in fact, contains a gap, then the second-stage device will coindex these elements. This coindexation will associate the empty operator with a theta-role (via the gap which is in a theta position) and cause it to be visible for semantic interpretation (cf. Chomsky 1981). If no gap is present in the clause, then, clearly, coindexation will not occur. In this case, the empty operator will lack both semantic features (because it is not associated with a theta role) and phonetic features (because it lacks phonetic content) and play no part in the final analysis of the sentence. In this way, its presence does not violate determinism.

2. Structural Ambiguity in Mandarin

Having sketched our initial assumptions concerning minimal commitment parsing, we turn now to a discussion of structural ambiguity in Mandarin. Consider the ambiguity represented in (8)

(8) wo renshi ni zuotian kanjian de ren
I know you yesterday see REL men
'I know the men who you saw yesterday'

Although this type of structure does not cause a conscious garden-path, a temporary ambiguity arises because the relative clause marker de occurs to the right of the clause. Thus, at the point at which it is initially encountered, the NP ni is a potential direct object of the verb renshi. Given the parsing model we are assuming, the parser may safely assert that this NP is dominated by the VP headed by renshi because this does not entail that it is DIRECTLY dominated by the VP. As subsequent lexical material is encountered, additional domination statements can be made, embedding ni within the larger NP, ni zuotian kanjian de ren. Crucial to this analysis is the fact that the original assertion remains true of the final structure.

If the original dominance assertion had not been supplemented by additional assertions, i.e. if ni were, in fact, the direct object of renshi, then this

assertion would be interpreted as direct domination (see Marcus, Hindle, & Fleck 1983).

Thus, our analysis of the Mandarin ambiguity represented in (8) parallels the one given for the English ambiguity in (2). Each ambiguity is parsed without a garden-path effect, and each can be parsed deterministically, given that the initial structure does not involve the predicate direct domination.

The second ambiguity in Mandarin which we would like to discuss is illustrated in (9).

(9) Zhangsan shuo Lisi bu renshi (ta)
Zhangsan said Lisi not know him
'Zhangsan said that Lisi didn't know him'

In (9), the object in the embedded clause may be phonetically empty. We will assume, following Huang (1984, 1987) that the structure underlying the string with the empty embedded object is (10). That is, the empty object is a variable bound by an empty operator in TOPIC position.

(10) $[_{TOP}\ O_1$ [Zhangsan shuo [Lisi bu renshi e_1

This analysis is motivated, in part, by the observation that, unlike an overt pronominal object, the empty object may not refer to Zhangsan. This would follow if the empty object were a variable which cannot be A-bound, as is true of the Wh-trace in the embedded clause in (11).

(11) [Who$_1$ [did John say [e_1 [Mary knew e_1

Assuming Huang's analysis of (9), we are presented with an ambiguity which is similar to that posed by parasitic gaps in English. That is, the presence or absence of a gap in (9) cannot be determined by the presence or absence of an overt antecedent. As with the parasitic gap structure (5), the solution is to allow the parser to posit an empty operator which will play no part in the final analysis of the sentence unless it is coindexed with a gap.

Although Huang's analysis does not include an intermediate trace in the embedded COMP, such a trace would be required by the Berwick & Weinberg parser as an available antecedent must exist within the parser's search space. Interestingly, Ni (1987) proposes such an analysis for independent reasons.

At this point it is important to note that the type of parsing model we have outlined does not predict a complete absence of garden-path effects. Rather, it predicts that garden-path effects will only arise in

those cases where the parser is forced to withdraw or alter an assertion concerning the computed structure. Consider (12), which produces a conscious garden path.

(12) Zhangsan yi du shu jiu diao le
Z. as soon as read book then fall ASP
'As soon as Z. (began to) read the book fell'

The garden-path effect occurs because the parser, at the point in the parse when shu appears, apparently asserts that this NP is dominated by the VP headed by du. Thus far, the parse is proceeding in a fashion similar to (8). The difference is that in (12), this assertion turns out to be incorrect. This requires that the assertion be altered and a conscious garden-path results.

Although we can offer an account of the garden-path effect in terms of incorrect assertions by the parser, we have yet to account for the existence of such assertions. Specifically, if the parsing model incorporates a property which permits delay, why doesn't this property insure that the parser will never be garden-pathed?

What we would like to suggest is that there exists a tension between the need to quickly structure incoming material so that it does not tax short-term memory resources, and the desire to delay commitment to avoid reanalysis. The task, then, of an efficient parser is to commit itself to as detailed a structure as possible while minimizing the need for reanalysis. For example, a recent proposal by Clark and Gibson (1988) requires that incoming NPs be licensed either by receiving a theta-role or abstract case in the sense of Chomsky (1981). Similarly, the parsing model outlined in Pritchett (1988) requires that the theta criterion be satisfied at each point in the parse.

If we consider (12) from this perspective, we see that the NP shu can only be licensed if it receives a theta-role and case from the verb. Locality constraints on theta-role and case assignment require the NP to be within the VP. A garden-path effect occurs when subsequent material casts this assertion into doubt. Interestingly, unlike its English counterpart, there is a grammatical structuring of the word string which is consistent with this initial assertion. Consider the structures in (13) and (14).

(13) Zhangsan yi du e shu jiu diao le
Zhangsan as soon as read (it) book then fall ASP
'As soon as Zhangsan began to read it, the book fell

(14) Zhangsan yi du shu e jiu diao le
Zhangsan as soon as read book (it) then fall ASP
'As soon as Zhangsan began to read the book, it fell

Unlike English, Mandarin permits empty subjects and empty objects. Thus, either (13) or (14) represent grammatical structures for the word string. What is of note here, is that the initial analysis of shu as the object of du does not force the reading represented in (14), thus allowing a deterministic parse and avoiding a conscious garden-path.

We have only intuitive data for examples such as these, but the parse sequence appears to be as follows: (i) shu is analyzed as the object of du; (ii) as processing of the next clause begins, there is conscious uncertainty as to the correct analysis; (iii) here we find that speakers diverge, some resolve the ambiguity as (13), some as (14). Although more research is needed, what may cause the conscious uncertainty is a conflict of otherwise automatic routines. That is, routines governing the licensing of NPs and routines governing the positing of empty categories.

Putting aside this issue of how the ambiguity in (13) and (14) is resolved, we can conclude from the analysis of (8) and (9) that our assumptions concerning minimal commitment parsing allow for a unified account of structural ambiguity resolution in English and in Mandarin. Unfortunately for this unified account, there is experimental evidence in English that the parser computes multiple analyses in parallel for the structural ambiguity illustrated in (2). We turn now to an examination of this evidence.

3. Evidence for Parallel Processing in English

Using a technique originally due to Wright and Garrett (1984), Gorrell (1988a, to appear) reports experimental results which indicate that for certain ambiguities, the parser computes multiple analyses in parallel. Wright and Garrett found that syntactic context exerted a robust influence on the recognition time for lexical decision targets. Specifically, they found that only targets belonging to syntactic categories predicted by the syntactic context produced faster reaction times. Significantly, they found that targets which represented grammatical, but optional continuations of the context patterned with targets representing ungrammatical continuations.

Gorrell used this technique to investigate the parser's response to structurally ambiguous syntactic

contexts. Consider the contexts in (15).

(15) a. Bill said that he discussed the answer to the problem VERB

b. Bill said that he found out the answer to the problem VERB

c. Bill said that he was happy the answer to the problem VERB

As with (2), (15b) contains a predicate (found out) which is ambiguous. Thus, when the parser encounters the NP the answer to the problem, it may be analyzed either as the object of the verb or as the subject of an embedded clause. Sentences (15a) and (15c) represent unambiguous controls corresponding to the two readings of the ambiguity in (15b). In (15a), the answer to the problem can only be analyzed as the object of the verb. In (15c), it can only be analyzed as the subject of an embedded clause.

Numerous studies (e.g. Frazier and Rayner 1982) have demonstrated that the preferred resolution of the ambiguity in (15b) is to analyze the NP following found out as its object. If this is the only analysis computed by the parser, or if the parser delays in committing to an analysis, then we would expect that lexical decision times for verb targets would be the same for (15a) and (15b). Because the context (15c) requires a verb, we would expect faster reaction times to verb targets with this context. Conversely, if the parser computes both readings of the ambiguity in (15b), then we would expect reaction times for verb targets to be the same for (15b) and (15c), with RTs for (15a) being significantly longer. The results are given in Table 1.

Table 1

Results from Gorrell (1988a)
RTs and Percent Correct for Context/targets Pairs
(Verb Targets)

Context	NP/S Complement Ambiguity
Simple (15a)	733 (99%) *
Ambig. (15b)	693 (99%) **
Complex (15c)	682 (99%) **

The results confirm the prediction of the parallel hypothesis and argue against both the serial and delay hypotheses. This is because contexts such as (15b) and (15c) patterned together, both producing RTs significantly faster than contexts such as (15a). Only the parallel hypothesis would predict that the ambiguous context would produce faster RTs for verb targets, because it is only this hypothesis which predicts that the parser will compute an analysis which would predict the appearance of a verb. Recall, Wright and Garrett (1984) report that it is only targets which represent predicted continuations of the context string which produce faster RTs. A delay model would not have computed such a structure, although it would have computed a structure which would have permitted a verb as a continuation.

Given these experimental results, we are now in a position where we must attempt to reconcile the apparent success of minimal commitment parsing models in accounting for cross-linguistic ambiguity resolution, with contradictory evidence for parallel processing.

4. Structural Ambiguity and Syntactic Information

If we look again at the ambiguity studied in Gorrell (1988a), we see that the parser is able to compute multiple readings based on the subcategorization frames of the ambiguous verb. Verbs such as know or find out are compatible with either nominal or sentential complements. The experimental evidence is that the parser makes rapid use of subcategory information in computing syntactic analyses (Gorrell 1988b).

In Section 2. above we suggested that the parser responds to ambiguities such as (8) in Mandarin by asserting only that the NP ni is dominated by the VP headed by renshi. This has the effect of delaying commitment to a particular analysis. Yet in the previous section we argued that for English examples such as (2) and (15b), the parser does not delay in its commitment, but rather pursues a strategy of computing multiple analyses in parallel.

This apparent contradiction can be overcome if we look at these ambiguities from the perspective of what type of information is available to the parser at the onset of an ambiguity. As noted, for the English examples, the subcategorization information of the verb is available, and analyses based on this information are pursued. In the Mandarin example (8), at the point at which the NP ni is encountered, there is no information available which would justify analyzing it as embedded

within a larger NP. This information, in the form of the relative clause marker, comes later in the parse.

Returning to our example (12) and its English counterpart, it appears that the parser would have access to the information that du may occur with or without an object, yet it appears that only one analysis is pursued. A plausible explanation for this is that it is only the reading where the NP shu is analyzed as the direct object which licenses this NP, i.e. under this reading it can receive a theta-role and case. Similarly, the Clark and Gibson parser will only pursue analyses in which the NP is licensed.

The picture which emerges is one in which the parser pursues all analyses for which it has specific lexical or syntactic information, but delays commitment in those cases where sufficient information is not available.

5. Conclusion

We can summarize our conclusions as follows.

(16) The Parser's Response to Structural Ambiguity

(i) Minimize the need for reanalysis.

(ii) Compute multiple analyses based on available lexical and syntactic information

(iii) Delay commitment to a unique analysis if sufficient information is unavailable

(iv) Do not postpone a commitment if it leaves lexical material unlicensed (or unstructured)

The parser minimizes the need for reanalysis by quickly and efficiently using lexical and syntactic information to build a structure (or structures) compatible with the word string. Multiple syntactic analyses are computed only when the available information indicates which analyses to build. If an ambiguity is encountered but the necessary information for computing multiple analyses is lacking, the parser delays commitment to a particular structure.

Finally, there is a constraint on the parser's delay capability which ensures that the parser will not respond to ambiguity by simply assembling a series of phrases (or lexical items) dominated by the root S. That is, phrasal categories must be licensed as they are processed. It is this latter constraint which leads to conscious garden-path effects.

Thus, the parsing design we have outlined here

constrains both the parser's capacity for computing multiple analyses as well as it's capacity for delaying commitment to a particular analysis.

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